CV HW2

Group 23

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Introduction

Task 1 - Hybrid image

An image can be decomposed by Fourier tranform, which including many frequencies signals. A image filters only high frequencies is so called high-pass image; similarly, a image filters only low frequencies is low-pass image. An hybrid image combines two images with one high-pass and one low-pass

Task 2 - Image Pyramid

The task of detecting a target pattern that may appear at any scale can be approached in several ways.
A much more efficient approach is Image Pyramid. The image pyramid is a data structure designed to support efficient scaled convolution through reduced image representation. It consists of a sequence of copies of an original image in which both sample density and resolution are decreased in regular steps.

Task 3 - Colorizing the Russian Empire

Prokudin-Gorskii used an early color technology that record three different exposures of every scene onto a glass plate using red, green and blue filter. In order to recover to a single RGB color image, extract the three color channels from the glass plate, then align the images one above the other.

Implementation procedure

Task 1 - Hybrid image

A image can apply a filter by a kernel:

$$B_{ij} = \sum_{u,v} H_{u,v} \cdot F_{i,j}$$

Where B_{ij} is the output image, H is the kernel filter, and F is the input image.

A filter can be an ideal filter or a Gussian filter, where an ideal filter simply apply cut-off filtering and the Gussian filter apply the Gussian function.

The Gussian filter function with variance σ and center (x, y) is the function:

$$g(x, y) = e^{\frac{-(x^2+y^2)}{2\sigma^2}}$$

When we want to use the Gussian filter to do a high-pass filter, we need to set kernel H to $1 - g(x, y)$, if we want to do a low-pass filter, the kernel H is $g(x, y)$.

During the filtering, F is defined as Fourier tranform of the image, since we want to filter frequencies.

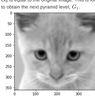
Once we get the filtering output R, we need to do inverse Fourier tranform to get the original visible image.

Task 2 - Image Pyramid

Gaussian Pyramid

Firstly, we used imagelo to read the image and transform the image to grayscale.

G_0 is equal to the original image. This is low-pass-filtered and subsampled by a factor of two to obtain the next pyramid level, G_1.



G_i is then filtered in the same way and subsampled to obtain G_{i+1}. Further repetitions of the filter/subsample steps generate the remaining pyramid levels. To be precise, the levels of the pyramid are
obtained iteratively as follows. This is low-pass-filtered and subsampled by a factor of two to obtain the next pyramid level,
For $0 < l < n$:
$G_l(i,j) = \sum_m \sum_n w(m,n) G_{l-1}(2i + m, 2j + n)$
(w(m, n) is "generating kernel")

Laplacian Pyramid

Interpolation can be achieved by reversing the REDUCE process. We call this an EXPAND operation. Let $G_{l,j}$ be the image obtained by expanding G_l k times. Then $G_{l,k} = EXPAND(G_{l,k-1})$ ie. to precise, $G_l 0 = G_l$ and for $k > 0$.

$$G_{l,k}(i,j) = 4 \sum_m \sum_n G_{l,k-1}(\frac{i-m}{2}, \frac{j-n}{2})$$

The levels of the bandpass pyramid, $L_0, L_1, ..., L_d$, may now be specified in terms of the lowpass pyramid levels as follows:

$$L_l = G_l - EXPAND(G_{l+1})$$

Task 3 - Colorizing the Russian Empire

In order to align the given three raw images, we perform Normalized Cross-Correlation algorithm to compute the similarity between given template and image. The algorithm is shown as follow:

$$h(m,n) = \frac{\sum_{k,l}[g(k,l) - \bar{g}][f(m+k, n+l) - \bar{f}_{m,n}]}{\{\sum_{k,l}[g(k,l) - \bar{g}]^2 \sum_{k,l}[f(m+k, n+l) - \bar{f}_{m,n}]^2\}^{0.5}}$$

where g is template and f is our target image.
In this task, G and R images are templates and B is the image we want to align. The template shift from top left corner with target image.

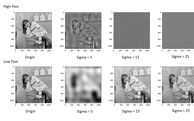
We use `np.roll` to implement the shifts. We compute NCC after every shift. The offset corresponding to the largest NCC value is most likely to be the alignment we want. The overall algorithm is shown below:

```
Score = -inf
for i in range:
    for j in col:
        similarity = NCC(target, template)
        if similarity > Score
            Score = similarity
            offset = (row, col)
return offset
```

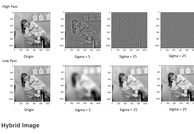
Experimental Results

Task 1 - Hybrid image

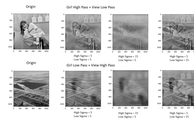
Ideal Filter



Gaussian Filter



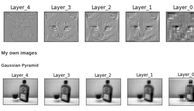
Hybrid Image



Task 2 - Image Pyramid

Homework data

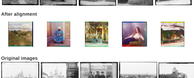
Gaussian Pyramid



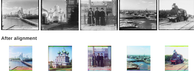
Laplacian Pyramid

My own images

Gaussian Pyramid



Laplacian Pyramid

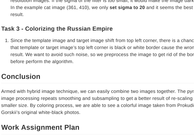


Task 3 - Colorizing the Russian Empire

Original images

After alignment

Original images



After alignment

Discussion (what difficulties you have met? how you resolve them?)

Task 1 - Hybrid image

1. During processing a hybrid image, if two images sizes are different, it is required to re-scale two image to the same size.
2. In a hybrid image, the clear part should be high-pass, and the fuzzy part should be low-pass. How to set the sigmas for high-pass and low-pass is depends of the effect we want.

Task 2 - Image Pyramid

1. After trying both **Box Filter** and **Gaussian Filter**, Gaussian has the better result. **Box Filter** would cause some box noise in low resolution. Therefore, we use the **Gaussian Filter** to filter the low frequency.
2. It would cause some error in **odd number shape**, when we expanded the image to the lower layer shape. We use **slice** to correct the expand image's shape to solve the problem.
3. We don't know how to **decide the sigma** of the filter. However, we tried some high resolution images. If the sigma of the filter is too small, it would make the image darker. In the example cat image (360, 410), we only **set sigma to 20** and it seems the best result.

Task 3 - Colorizing the Russian Empire

1. Since the template image and target image shift from top left corner, there is a chance that template or target image's top left corner is black or white border cause the wrong result. We want to avoid such noise, so we preprocess the image to get rid of the borders before perform the algorithm.

Conclusion

Armed with hybrid image technique, we can easily combine two images together. The pyramid image processing repeats smoothing and subsampling to get a better result of re-scaling to a smaller size. By coloring process, we are able to see a colorful image taken from Prokudin-Gorskii's original white-black photos.

Work Assignment Plan

- Liu, An-Chi: task 1
- Chen, Shao-Yun: task 2
- Ko, Ruo-Lin: task 3